Justification for Use of Monthly, Growing Season and Annual Averaging Periods for Expression of WPDES Permit Limits for Phosphorus in Wisconsin

Averaging Periods by Receiving Waterbody Type and Range of WQBEL Concentrations		
WQBEL	Rivers, streams, impoundments and lakes/reservoirs with average water residence times of less than one year	Lakes with average water residence times of greater than or equal to one year
Greater than 0.3 mg/L	Monthly average	Monthly average
Less than or equal to 0.3 mg/L	Monthly* or six month average (May 1 to October 31 and November 1 to April 30). When the WQBEL as a six-month average is included in the permit, a monthly average limit of 3 times the calculated concentration limit in ss. NR 217.13 and NR 217.14, shall also be included in the permit.	Monthly*or six month average (May 1 to October 31 and November 1 to April 30) or annual average. When the WQBEL as a six-month average or annual average is included in the permit, a monthly average limit of 3 times the calculated concentration limit in ss. NR 217.13 and NR 217.14, shall also be included in the permit.
For approved TMDLs, the expression of limits must be consistent with the assumptions and requirements of the TMDL, but not greater than the periods expressed above.		
* Atypical or uncommon situations will be addressed on a case-by-case basis. These include discharges to small inland lakes with water residence times of less than one year where it is possible that a six month averaging period may not be appropriate and a monthly average limit calculated under ss. NR 217.13 and NR 217.14 may instead be necessary.		

Pertinent Federal Regulation

Section 40 CFR 122.45 (d) of Federal Regulations, requires NPDES permits, including delegated state permits, to express water quality based effluent limits for continuous dischargers, including those for phosphorus, as average weekly and average monthly limitations for POTWs and maximum daily and average monthly limitations for other than POTWs, unless impracticable. Federal regulations do not describe criteria for determining when limits are impracticable, nor does EPA provide guidance on how to make a determination of impracticability.

EPA has made a finding for Chesapeake Bay that impracticability can be based on the nature of the water quality problems. For Chesapeake Bay, EPA determined that daily maximum, weekly average and monthly average effluent limits are impracticable due to the nature of nutrient related water quality problems in the bay. In making this determination, EPA concluded that annual averaging periods were practicable for Chesapeake Bay. This does not automatically infer that annual averaging periods are practicable elsewhere. It merely states that the nature of the water quality problem can be used to determine impracticability.

Principles

- Averaging periods should be consistent with the technical analysis and rationale supporting the adopted phosphorus water quality standards criteria. The Wisconsin phosphorus criteria were developed based on correlations between <u>median growing season phosphorus concentrations</u> and biotic indices.
- Averaging periods should be consistent with EPA guidance for nutrient criteria development.
- The averaging period must take into account critical conditions in the receiving water or downstream water.
- Averaging periods should be compatible with tools, such as models, used to manage the lake, reservoir, stream or river.
- Shorter averaging periods should be used where the frequency, duration or magnitude of the difference between the limit and water quality standards criterion is greater. Longer averaging periods may be used where the difference is less, especially as the discharge limit is the same as the water quality criterion.

Technical Justification

A. Streams and Rivers

Conclusions:

1. It is impracticable to establish maximum daily and average weekly phosphorus limits under 40 CFR 122.45(d) due to the way waterbodies respond to phosphorus loading and due to the manner in which phosphorus water quality standards criteria for Wisconsin were derived.

2. Due to the manner in which the Wisconsin phosphorus criteria were derived, it may be impracticable to establish average monthly limits under 40 CFR 122.45(d) when the magnitude of the calculated water quality based effluent limit is 0.3 mg/L or less.

3. Based on available literature and the judgment of national experts, EPA criteria development guidance clearly calls for states to use <u>seasonal or annual mean or median values</u> in development of nutrient criteria.

4. Wisconsin's wadeable streams exhibit conditions similar to those described in EPA guidance.

5. Wisconsin's approved criteria for both wadeable streams and nonwadeable rivers were derived using correlations between <u>growing season median</u> phosphorus concentrations and community biotic indicators.

6. Although nonwadeble streams exhibit higher concentrations of suspended algae and suspended algae may be more responsive to changes in phosphorus concentrations, acute conditions, such as low dissolved oxygen concentrations, are not exhibited.

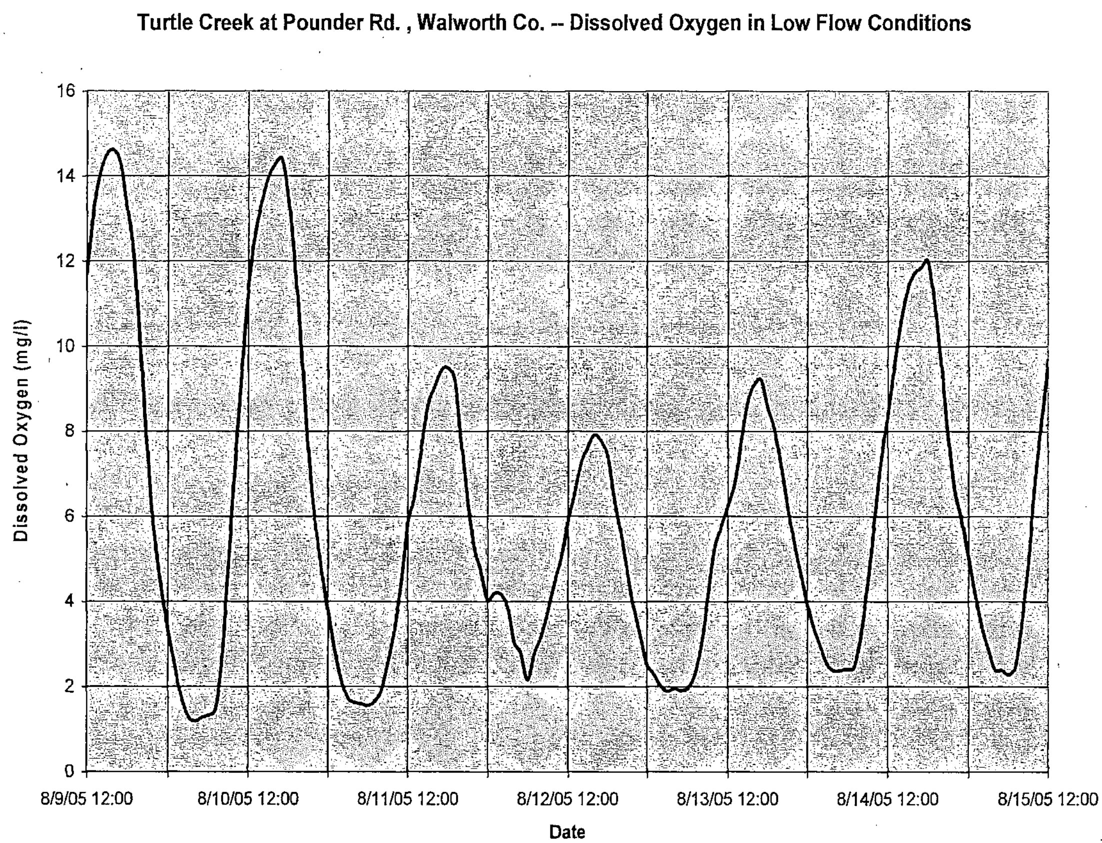
7. If averaging periods for WPDES permits should reflect methods and data used to develop phosphorus criteria, generally a growing season averaging period is warranted.

8. Since the risk of impact increases with nutrient concentrations (as well as frequency and duration), it is prudent that permits with higher concentration limits should have shorter averaging periods. Similarly, discharges with lower limits that are set at the water quality criterion concentration could have longer averaging periods taking the background concentration and available dilution into account.

EPA Guidance

EPA's "Nutrient Criteria Technical Guidance Manual: Rivers and Streams" (EPA, July 2000) based on the knowledge and experience of many experts and reviews of the scientific literature, makes numerous references and suggestions to use of seasonal or annual mean or median values in deriving nutrient criteria. For example, in Chapter 6 of the guidance manual, explicitly identifies use of annual mean nutrient concentrations in developing relationships with the 75th percentile of mean algal biomass (page 60). EPA cites work by Biggs (1995 and 2000) as justification for use of this approach and the use of the annual mean values. Also, EPA guidance suggests water quality sampling procedures and data analysis approaches based on seasonal monitoring.

For macrophyte dominated streams the EPA guidance and scientific literature infer that seasonal or even annual analyses may be appropriate. In section 3.3, EPA discusses impacts of large diurnal dissolved oxygen fluctuations due to photosynthesis/respiration by dense macrophyte masses. Later in the guidance EPA describes rooted macrophytes taking up phosphorus from interstitial waters of bottom sediments; largely uncoupling macrophyte growth with short-term fluctuations of phosphorus concentrations in water columns. Mace et. al, Wisconsin DNR researchers, found a high correlation between late-summer biomass and mean summer phosphorus concentrations in macrophyte dominated streams (WDNR 1984).



The methods and processes used by benthic algae to take up phosphorus vary with the type of benthic algae. Filamentous algae with greater exposure to the water column may be more responsive to short-term changes in phosphorus concentrations than the more prostrate forms. Regardless of the type or processes for uptake, the primary impact relates to the mass of the accumulated algae and the factors of scour and grazing relate to time and rate of accrual (growth minus scour and grazing). High flow velocities associated with rainfall scour benthic algae and reduce the accumulated biomass.

Biggs (2000) empirically expresses the mean monthly biomass as a function of the days of accrual and the nutrient supply. This, of course, takes a very complex set of interactions involving a number of factors, including light, temperature, periodic sloughing losses, grazing by invertebrates and fish, and presents a simplified relationship. Specifically, Biggs' relationship is as follows:

$$B^* = k_1 d_a + k_2 n + c,$$

Where:

B^* is the mean monthly biomass of benthic algae;

d_a is days available for biomass accrual;

n is a measure of nutrient supply;

k_1 and k_2 are coefficients; and

c is a constant.

A consequence of the Biggs relationship is that to achieve the same biomass, streams with lower concentrations of nutrients will have a shorter accrual period of time and vice versa. Biggs concludes that that the frequency of high biomass events sufficient to create eutrophic conditions (200 mg/m^2) increases greatly when the days of accrual exceed 50 days. Again, the number of days varies with the nutrient concentration. Biggs' conclusions were based on unshaded streams. Streams with partial shading will have a longer number of accrual days. Biggs also did his research on streams with gravel or cobble substrata. His model will overestimate benthic algae mass for streams with silt or sand substrata. Thus, longer accrual periods may be pertinent to streams with silty or sandy substrata.

<u>Wisconsin Situation and Phosphorus Criteria Development</u>

The waterbody types and common nutrient related situations for Wisconsin rivers and streams are summarized on the attached table. Wisconsin wadeable streams with high phosphorus concentrations – at least those not shaded or very turbid – tend to exhibit a phosphorus response similar to the conditions and assumptions contained in EPA's technical guidance. That is, they tend exhibit a nutrient response as rooted macrophytes, benthic algae or a mix of the two. Generally light will penetrate through much of the water column or even to the bed of the stream to provide conditions suitable for rooted macrophyte or benthic algae growth. Relatively few of Wisconsin's wadeable streams have high suspended algae concentrations.

This situation is best documented by the study of more than 240 Wisconsin streams used to develop nutrient criteria, "Nutrient Concentrations and Their Relations to Biotic Integrity of Wadeable Streams in Wisconsin" (USGS Professional Paper 1722). Appendix 2 of this report shows the extent of benthic algae and rooted macrophyte growth in the study streams. Not unexpectedly, this study also found relatively low suspended chlorophyll a concentrations. The median growing season suspended chlorophyll-a concentrations were 1.0 to 1.7 ug/L and the upper 95-percent confidence limit were 1.6 to 2.2 ug/L, depending on the phosphorus zone within the state. (USGS Professional Paper 1722, Table 22). Only nine of 240 wadeable streams had chlorophyll a concentrations exceeding 10 ug/L, and of those nine, two had sample sites immediately downstream of eutrophic impoundments and one is more appropriately considered as a non-wadeable stream.

Given the recommendations contained in EPA's guidance and a review of the available response information, the Wisconsin phosphorus criteria were developed based on correlations between <u>median growing season phosphorus concentrations</u> and biotic indices. The statistical analysis of the nutrient concentrations and their correlation with selected biotic indices is discussed at great length in the USGS Professional Paper 1722.

The companion study of 42 sites on Wisconsin non-wadeable streams and rivers found greater concentrations of suspended algae and a strong correlation between the median growing season total phosphorus and suspended chlorophyll-a concentrations. For much of these rivers, the water depth is great enough to prevent sufficient light penetration to the bed of the river and benthic algae samples were not taken. Eighteen of these 42 sites had suspended chlorophyll-a concentrations of greater than 10 ug/L. Of these 18 sites, 11 had median concentrations of more than 20 ug/L. While these higher algae concentrations may raise a concern, in these larger rive systems we tend not to see the minimum dissolved oxygen concentrations that tend to be seen in wadeable streams. For example, diurnal swings in smaller streams may have a minimum dissolved concentration of 2 mg/L as shown for Turtle Creek in the figure below. For rivers, it is believed that the minimum dissolved oxygen concentrations tend to be 4 mg/L or higher, similar to what was found in Minnesota. In a study of 34 rivers, MPCA found only one site where the minimum diurnal concentration of dissolved oxygen fell below 4.0 mg/L (Figure 10, MPCA 2010).

B. Lakes and Reservoirs

Conclusions:

1. It is impracticable to establish maximum daily and average weekly phosphorus limits under 40 CFR 122.45(d) due to the way waterbodies respond to phosphorus loading and due to the manner in which phosphorus water quality standards criteria for Wisconsin were derived.

2. Due to the manner in which the Wisconsin phosphorus criteria were derived, it may be impracticable to establish average monthly limits under 40 CFR 122.45(d) when the magnitude of the calculated water quality based effluent limit is 0.3 mg/L or less.

3. Based on available literature and the judgment of national experts, EPA criteria development guidance clearly calls for states to use <u>seasonal mean concentrations to assess in-lake conditions</u>.

4. Some measure of water residence time, water retention time, flushing rate or some similar factor are used in all or nearly all lake models used in Wisconsin and those described in EPA guidance to relate phosphorus loading to in-lake conditions.

5. For lakes with long water residence times, the impact of phosphorus loads from the entire year will be exhibited in the growing season.

6. Wisconsin's approved criteria were derived using correlations between <u>growing season mean</u> phosphorus concentrations and a variety of growing season response indicators.

<u>EPA Guidance</u>

Chapters 5, 6 and 7 of EPA's "Nutrient Criteria Technical Guidance Manual: Lake and Reservoirs" (EPA, 2000) clearly suggests to states that in-lake response conditions should be assessed using mean seasonal concentrations. Generally, this is viewed as a "growing" season and in northern states, such as Wisconsin, the growing season of May through September is typically used.

As described in Chapter 9 of EPA's guidance, various models may be used to quantitatively relate the timing and amount of phosphorus loading to in-lake conditions. Many, if not all, use some measure of water residence time, flushing rate or similar parameter to account for mixing of phosphorus inputs within the lake, and, more importantly, settling of phosphorus. That is, the longer the residence time, the less variability of in-lake responses to phosphorus loadings and the greater the settling of phosphorus within the lake. For deeper, seasonal stratified lakes, the in-lake response relates to annual or multi-year loadings. At the other extreme, conditions within lakes or reservoirs with short residence times may relate to seasonal loadings. For example, early spring loadings may flush through a reservoir with a relatively short residence time and have relatively limit impact on growing season in-lake response conditons.

Wisconsin Situation

Wisconsin's phosphorus criteria for lakes are based primarily on:

- Minimizing nuisance (less than 5% risk) and severe nuisance (less than 1% risk) algal conditions;
- Minimizing the shift of aquatic plant communities in shallow lakes from macrophyte dominated to algae dominated;
- Maintaining balanced fish communities.

In addition, there is a stated intent to prevent harmful aquatic bloom conditions. However, this was a lack of quantitative information to derive numerical criteria.

Critical Condition. Generally, the mid-growing season, July and August, is considered the critical period for nuisance algae conditions in most Wisconsin lakes and reservoirs. The presence of phosphorus, warm water temperatures and abundant light combine to favor the mid-to-late growing season as the critical period. This doesn't mean that discharges prior to or after this critical condition are unimportant. On the contrary, there is a lag time between the time phosphorus reaches the lake or reservoir and when the nuisance conditions are exhibited. For lakes with very long water residence times, such as more than one year, there is substantial mixing within the lake water column resulting in relatively little difference in response between phosphorus loads entering the lake in January verses those entering in June. For lakes with short residence times, the time of the year may be very important. Some form of water residence time or lake flushing rate is an important factor in nearly all lake models used in Wisconsin.

Technical Basis. Wisconsin's phosphorus water quality standards criteria for all lake types were developed using the mean or average condition is the growing season. Water quality samples are routinely collected in June through September or June or June through August depending on the parameter. The sample results are averaged over the growing season and, where possible, averaged over a number of growing seasons. Thus, both the basis for the criteria and routine use of tools for management programs base conditions on what responses will likely occur for given phosphorus conditions, but not the statistical outlier condition that is likely to occur very infrequently.

References

"Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs", EPA, April 2000.

"Nutrient Criteria Technical Guidance Manual: Rivers and Streams", EPA, July 2000.

Robertson et. al. "Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin", USGS Professional Paper 1722, 2006

Robertson et. al. "Nutrient Concentrations and Their Relations to the Biotic Integrity of Nonwadeable Rivers in Wisconsin", USGS Professional Paper 1754, 2008

"Impacts of Phosphorus on Streams", WDNR, April 1984.

Biggs, Barry, J. F., "Eutrophication of Streams and Rivers: Dissolved Nutrient-Chlorophyll Relationships for Benthic Algae", Journal of North American Benthological Society, 2000.

Heiskary et. al., "Minnesota River Nutrient Criteria Development", Minnesota Pollution Control Agency, November 2010.

Summary of Waterbody Types, primary nutrient related impacts, extent found in Wisconsin and comments related to averaging period.

Waterbody Type	Primary concerns	Extent in Wisconsin	Comments Related to Averaging Period
		Streams and Rivers[1]	
Stream – rooted macrophyte dominated	Low diurnal dissolved oxygen levels (e.g. 2 mg/L) near dawn in mid summer (generally non-lethal) habitat degradation due to sediment capture	Very common; may be most common situation in wadeable streams Focus of Wisconsin DNR study report "Impacts of Phosphorus on Streams", 1984	Since rooted macrophytes receive phosphorus from interstitial waters of bottom sediments, not responsive to short-term fluctuations in water column phosphorus Growing season means or medians generally used to assess rooted macrophyte dominated streams
Stream – benthic algae, including filamentous algae and attached algae	Low diurnal dissolved oxygen in mid summer; loss of habitat for certain aquatic insects; loss of visibility for sight-feeding fish	Common throughout state Focus of Wisconsin DNR study report "Impacts of Phosphorus on Streams", 1984	Subject to scour during periods of high velocities; periods of accrual before critical conditions occur; Biggs (2000) suggests 50 day accrual period. Growing season means of median generally used to assess
Stream – floating macrophytes (duckweed)	Floating algae restricts surface water re-aeration	Found, but uncommon in wadeable streams	Not well understood; no accepted sampling protocol

[1] Many Wisconsin wadeable streams do not exhibit responses to phosphorus due to shading from trees or grasses or due to lack of light penetration due to turbid conditions. Downstream waters, however, may exhibit responses to phosphorus.

Waterbody Type	Primary concerns	Extent in Wisconsin	Comments Related to Averaging Period
Stream – suspended algae	May result in low dissolved oxygen	Uncommon in wadeable streams. 9 of 240 streams in Wisconsin wadeable stream study had median suspended chlorophyll a concentrations exceeding 10 ug/L.[2]	May see response to change in nutrient concentrations.
Rivers (non-wadeable) -- suspended algae[3]	May result in low dissolved oxygen; generally considered to have minimum dissolved oxygen concentrations of more than 4 mg/L (MPCA 2010)[4].	Common in 46 "rivers" listed in s. NR 102.06, Wis. Adm. Code. 18 of 42 study sites had median growing season suspended chlorophyll a concentrations of greater than 10 ug/L. Suspended algae contributes to turbid conditions	May see response to change in nutrient concentrations, however, response tempered by volume of water and surface area reaeration.

[2] At least two of the nine wadeable streams were sampled downstream from eutrophic impoundments. One of the nine is generally considered as a non-wadeable stream and classified as a river in s. NR 102.06, Wis. Adm. Code.
[3] Generally have great enough water depths such that adequate light does not penetrate to bottom. Bed surveys for macrophytes and benthic algae were not anticipated and, therefore, not included in the study.
[4] Conditions considered similar to those in Minnesota rivers where in nearly all study rivers minimum dissolved oxygen conditions were above 5 mg/L.

Waterbody Type	Primary concerns	Extent in Wisconsin	Comments Related to Averaging Period
Lakes and Reservoirs			
Great Lakes, excluding Lower Green Bay[5]	Accumulation of filamentous algae mats on shores inhibiting recreational uses	Common on Lake Michigan and Green Bay shores; not common along Lake Superior likely due to colder water temperatures.	Not considered responsive to short duration changes in water column concentrations due to very long water residence times. Conditions in nearshore waters likely the response to mixing of tributary waters and the upwelling of open waters. Cladophora associated with zebra and quagga mussel accumulation of phosphorus and excretion of phosphorus.
Deep stratified drainage lakes, including two-story fishery lakes	Growth of algae in epilimnion and loss of dissolved oxygen in hypolimnion. Inhibits recreational uses, may result in change in aquatic community, and may result in loss of cold water species	Common in Wisconsin, but few receive discharges from wastewater treatment plants[6]	These lakes tend to have long water residence times, some may exceed a year. Modeling of lakes generally based on annual phosphorus inputs.

[5] Lower Green Bay exhibits conditions similar to the large lakes and reservoirs. The water residence time for Lower Green Bay is less than one year.
[6] Big Green Lake is an example. Ripon POTW discharges to Silver Creek which flows to Big Green Lake.

Waterbody Type	**Primary concerns**	**Extent in Wisconsin**	**Comments Related to Averaging Period**
Deep stratified seepage lakes	Similar to deep stratified drainage lakes	Common in Wisconsin, but few receive discharges from wastewater treatment plants[7]	These lakes tend to have long water residence times that may or may not exceed a year. Modeling of lakes based on annual phosphorus or growing season inputs.
Shallow drainage and seepage lakes	Aquatic community shift from macrophytes to algae; inhibits recreational uses	Common in Wisconsin, but few receive discharges from wastewater treatment plants[8]	Generally have water residence times of less than a growing season.
Large shallow lakes and reservoirs	Growth of nuisance algae inhibits recreational uses, may result in change in aquatic community.	Common, including Winnebago Pool lakes and reservoirs along the Wisconsin River	Water residence times vary, but generally less than one year. For some, phosphorus loads during spring runoff events may rapidly pass through the body of water emphasizing growing season contributions. Modeling of these lakes and reservoirs may be based on either annual phosphorus loads or growing seasonal phosphorus loads.
Impoundments as defined in s. NR 102.06	Respond similar to flowing streams or rivers	Common	See streams and rivers above

[7] Silver Lake in Manitowoc County is an example. Silver Lake receives direct discharge from the Silver Lake Convent and College wastewater treatment plant.
[8] Goose Lake in Columbia County is an example. Goose Lake, a very shallow pond that supports a large goose population, received discharge from Arlington's POTW.